A SIMPLE PENETROMETER FOR LABORATORY AND FIELD USE

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Abstract

An inexpensive and easily constructed penetrometer is described and compared with other designs.

Introduction

Penetrometers have often been used to relate feeding preferences of phytophagous insects to the mechanical hardness of plant tissues and penetrometer designs have ranged from very simple to fairly complex. We used selected features of earlier designs in a penetrometer to measure the hardness of the epidermis of water hyacinth, *Eichhornia crassipes* (Mart.) Solms., because none of the earlier designs possessed the combination we required of simple construction, low cost, easy operation in the laboratory and the field, and the ability to repeat measurements with standard errors less than 10% of means with a sample size of ten.

Previous designs

The penetrometer devised by Williams (1954) to relate feeding preferences of acridid grasshoppers to leaf hardness was very simple and has been widely used (Tanton, 1962; Taylor and Bardner, 1968; Thomas, 1974). A leaf to be tested was placed across the mouth of a specimen tube and held taut by pressing a cork, penetrated by a glass capillary tube, into the specimen tube. A pin was placed into the capillary tube with the point resting on the leaf and sand was added to a receptacle attached to the head of the pin. The weight of sand needed to cause the pin to penetrate the leaf was measured. Different aspects of this basic design have been improved by various workers.

Leaf mounting

Thomas (1974) used glue to secure delicate leaves to the bottom of the cork to prevent stretching, while Feeny (1970), Beckwith and Helmers (1976) and Wint (1979) prevented stretching by clamping leaves between two flat surfaces.

Penetration

Feeny (1970), Beckwith and Helmers (1976) and Wint (1979) used a flat-ended rod rather than a pointed pin to simulate the shearing and tearing actions of insect mandibles. However, a pointed pin may be more appropriate for simulating penetration by hemipteran mouthparts.

Application of force

While Feeny (1970) continued to use sand to apply weight, Wint (1979) avoided having a separate weighing operation by using measured volumes of water. In designs unsuitable for use in the field, Cherrett (1968) applied force with a spring and pulleys while Beckwith and Helmers (1976) used a lathe carriage driven by an electric motor.

Description of the new design

The penetrometer (Fig. 1) consisted of a burette (not shown) which delivered water into a receptacle (a) which was fixed to a pin-holder with pin (b). The pin was introduced into a guide block (f) fitted with a glass capillary tube (e) which also penetrated the centre of the upper plate (d) of a leaf-holder. When a leaf was clamped between the upper (d) and lower (g) plates of the holder, the pin rested on the leaf surface until the weight in the receptacle was sufficient to force the pin through the leaf.

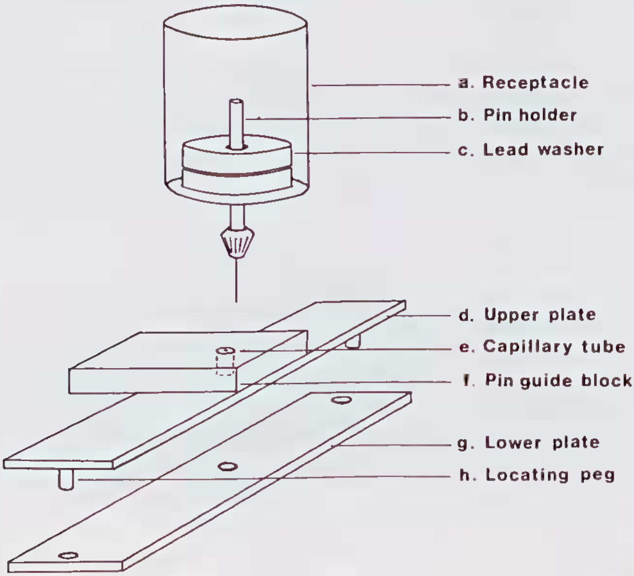

Fig. 1 The penetrometer

The burette accurately controlled water flow and measured the volume (i.e. weight) delivered. Preloading the receptacle with lead washers (c) of known weight allowed a greater range of hardness to be measured. The chuck-type pin-holder enabled easy exchange of pins of different diameters and its shank extended up inside the receptacle to locate preload washers. The points of pins were ground off to form a flat end to simulate shearing by mandibles of weevils and caterpillars which attack water hyacinth in Australia. This also made the moment of penetration easily discernible because flat-ended pins were found to penetrate more suddenly than pointed pins.

The leaf-holder was made of clear perspex to enable accurate positioning of leaves, necessary to avoid areas of leaf damage. The capillary tube (e) minimised friction on the pin which, after penetration, passed through a small hole in the lower plate of the holder. The upper and lower plates were aligned by locating pegs (h) and held together by clamps. During use the

guide block, made wider than the top plate, was clamped to a rigid stand. The lower plate was not used when measuring the hardness of robust structures, such as petioles of water hyacinth, which were simply held against the upper plate by hand.

Representative results

The repeatability of measurements was tested by finding the weights necessary to cause penetration at ten different places on a single sheet of carbon paper. Carbon paper was used because it required approximately the same weight for penetration as the epidermis of water hyacinth and because under the microscope it appeared to be of more uniform texture than alternative papers. With a pin of 0.85 mm diameter (0.57 mm^2 cross section), the mean weight required was 153.82 gm with a standard error of 2.27 or 1.5% of the mean, well within the limits of repeatability required. Table 1 presents typical measurements of water hyacinth hardness using the same pin and shows that variances were greater than with the carbon paper but, with one exception, standard errors were still within 10% of means.

TABLE 1
Estimates of the epidermal hardness, in gm required for penetration, of the laminae and petioles of the youngest five leaves of ten water hyacinth plants.

Leaf position	Lamina			Petiole		
	Mean	S.E.	S.E. as % of mean	Mean	S.E.	S.E. as % of mean
1	108.6	3.25	2.99	162.0	16.90	10.43
2	116.6	4.96	4.26	218.4	5.96	2.73
3	112.3	2.72	2.42	233.2	5.83	2.50
4	112.8	3.47	3.08	232.4	6.85	2.95
5	113.9	4.59	4.03	241.8	8.36	3.46

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